*P*Note 533

pH and Conductivity Calculations and Measurements
Relevant to the *P* Target Station

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Overview

During the most recent collection lens failure, it is believed that the conductivity measurement system failed. Evidence that the septum failed and released lithium into the water without tripping the conductivity interlock comes from measurements of the pH of the water and the fact that the pressure in the closed loop water system nearly doubled in twenty minutes. The interlock sum tripped on overpressure and approximately 1 liter of water was released from the relief valve. Given this set of circumstances, it seems prudent to calculate the expected lithium release into the water and the corresponding expected conductivity for the pH measured.

Li Chemical Reaction with Water

The following chemical reaction describes how lithium combines with water to produce lithium hydroxide plus hydrogen gas:

In this reaction, 1gm of *Li* combines with 2.59gm water to produce 3.45gm of lithium hydroxide plus .14gm of hydrogen gas. Since the molar weight of H_2 is 2 gm/mole, .14gm is .07 moles. There are 22.4 liters per mole of gas. Thus, 1gm of *Li* will produce 1.57 liters of hydrogen gas when combined with water.

pH Calculation

The measured pH of the water after the lens failure was 10.4. One can use this to calculate the molar concentration of lithium hydroxide in the closed loop system. Since lithium hydroxide is a base, the following equation applies:

$$14 - (-\log(x)) = 10.4 \longrightarrow x = .00025 \text{ moles/l}$$

Given that the dissociation constant for lithium hydroxide in water is .63, we have

$$k_B = .63 = \frac{[Li^+][OH^-]}{[LiOH]} = x^2/(m - x)$$

The solution to this equation is an m of .0002501 moles per liter. Since the water system holds roughly 60l, this gives us a total of .015 moles or .36gm since $LiOH$ is 24gm per mole. Since 1gm of Li gives 3.45gm of $LiOH$, this works out to .1gm of Li .

Conductivity Calculation

The conductivity as measured by a rectangular sensor or cell is represented by the following equation:

$$G = K \times A/l$$

Note that G is the conductivity in siemens, K is the solution conductivity in siemens per cm, A is the cell area and l is the cell length. To calculate K , one multiplies the molar conductivity for common ions at infinite dilution by the normality of the solution (in moles per cm^3). For $LiOH$, $\Lambda = \lambda_{Li^+} + \lambda_{OH^-} = 236.66$ $cm^2S/mole$. For the example above, the normality is .00025 moles/l or .25 $\mu moles/cm$. K_{sample} is $59 \mu S/cm$.

pH and Conductivity Measurements

After small measured samples of Li were placed in water, an Omega pH and conductivity meter was used to collect the data plotted in figures 1 and 2. Note that the results have been scaled to 60l so that they correspond to the operational situation.

Conclusions

Given that the pH measured just after the last failure is consistent with .1gm of Li both in calculation and measurement, the conductivity measurement

Figure 1. pH vs. m_{Li} in 60l of water.

Figure 2. K_{sample} vs. m_{Li} in 60l of water.

system should have read $59\mu S/cm$. From the liter of water expelled from the system to relieve overpressure, the amount of Li could have been as high as .6gm.

The discrepancy can be understood by noting that the system was partially drained twice before failure was declared. Thus, the pH may have been an underestimate. In any case, the conductivity readback was only $2 \mu S/cm$ and did not trip off the system. At the earliest opportunity, the system will be checked for device and amplifier calibration and/or failure. If any of the diagnostics fail in the future, it should be possible to quickly check water system samples for pH and conductivity directly and to compare the readings with the plots given in this document.

References

1. "CRC Handbook of Chemistry and Physics(73rd Edition)",ed. D.Lide, CRC Press,Boca Raton,1992.
- 2."pH and Conductivity",Omega Engineering Inc.,Stamford,CT.,1988.